MODEL 370

OPTOMETER

# OPERATING INSTRUCTION MANUAL

UDT INSTRUMENTS
A CEI Company

# MODEL 370

# OPTOMETER

UDT INSTRUMENTS, A CEI COMPANY
P/N 79-10-032
JULY, 1988
REVISION A

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## CAUTION

Each Model 370 is calibrated at the factory for the specific detector and accessories included with the instrument. Do not substitute different detector or accessories without verifying that the calibration is installed in the instrument.

The maximum input power level for this instrument assuming only a radiometric filter is used is 10mW total or 500mW/cm$^2$, whichever is less. Beyond these flux levels the detector becomes non-linear. Beyond 100mW total or 500mW/cm$^2$ there is a risk of irreversible detector damage.

Verify proper line voltage selection prior to operation. See rear panel switch for line voltage. Attempted operation at incorrect line voltage will cause catastrophic damage.

Disconnect AC line prior to removal of top cover to avoid electrical shock or accidental damage.

## SPECIFICATIONS

Display: Alphanumeric 16 lines, character liquid crystal, display update rate 2 to 4 readings/sec. 4 to 5 significant digits displayed. Contrast adjustment provided on panel. Touch selectable electroluminescent backlighting.

Controls: 10 touch sensitive controls set instrument function, also programmable through IEEE-488 interface.

Pushbutton power on/off with red LED power indicator.

Calibration: Calibration information stored in rear panel mounted EPROM. EPROM contains current measurement calibration for pico-ammeter function and calibration information on specified detectors.

Detector Inputs: Removable front panel BNC connector modules provided for detector connections.

Digital Interface: Standard IEEE-488 for instrument control and data exchange.

Power Required: 90-132VAC or 180-264VAC 47-440Hz, switch selected on rear panel, 12 VA max required. Fused at 1/8 A for 115VAC operation, 1/16 A for 230VAC operation. Uses slow blow fuses. Accepts 3AG, 0.25" (6mm) dia. x 1.25" (31mm) long fuses. Male IEC line connector provided. Rear panel DC input 9 to 15 VDC, 500m A max, unswitched. Mating connector is Switchcraft type 760.

Dimensions: 3.69" (94mm) H x 8.5" (216mm) W x 9.25" (235mm) D.

Weight: 4.0 pounds (1.8Kg)

Operating Temperature Range: $0^{o}C$ to $45^{o}C$
Storage Temperature Range: $-20^{o}C$ to $60^{o}C$

A/D Converter: Resolution: 15 bits plus sign
Full Scale Voltage: 2.5V
Sampling Rate: 2 to 4 readings per second

Transimpedance Amplifier System:
Gain Ranges: $10^{3}$ to $10^{9}$V/A, decade steps
Input Current Error, Temperature Drift: 2pA max, doubles every $10^{o}C$
Input Voltage Error: 10uV max over temp.
Maximum Operational Input Current: 1.5mA
Maximum Safe Input Current: 7.5mA

| FULL SCALE CURRENT | RESOLUTION | UNCERTAINTY @22 °C % OF READING + 2 COUNTS | TEMPERATURE DRIFT % OF READING | FRONT END AMPLIFIER RESPONSE TIME 10%-90%, mS | INPUT RESISTANCE OHMS |
|---|---|---|---|---|---|
| 1nA | 0.1pA | 0.7% | 0.05% | 150mS | <1000 |
| 10nA | 1pA | 0.7% | 0.05% | 150mS | <1000 |
| 100nA | 10pA | 0.15% | 0.02% | 150mS | <10 |
| 1uA | 100pA | 0.11% | 0.02% | 150mS | <10 |
| 10uA | 1nA | 0.15% | 0.02% | 120mS | <1 |
| 100uA | 10nA | 0.11% | 0.02% | 120mS | <1 |
| 1mA | 100nA | 0.13% | 0.02% | 120mS | <1 |

# 1.0 GENERAL INFORMATION

## 1.1 Introduction

The UDT Model 370 Optical Power Meter is a microprocessor-based radiometer/photometer of the quality synonymous with UDT instrumentation. Human engineering and innovative features permit an operator to make a variety of precision optical measurements.

Versatility and accuracy are the prime design parameters incorporated in the UDT Model 370. By selecting from the broad range of available detector/filter heads and accessories, the user may tailor the Model 370 to any specific application requirement and can easily modify the instrument to meet future application needs.

## 1.2 Applications

Applications of the model 370 include:

Radiometry from 200 to 1800nm
Photometry
Laser Power Measurement
Cathode Ray Tube Luminance
Fiber Optics Power and Loss Measurements
Remote Controlled Monitoring/Automatic Testing
Measurements with Optical Equipment such as Scanning Monochrometers

## 1.3 Accessories

The instrument is designed to accept all standard UDT radiometric/photometric accessories including microphotometer and telephotometer attachments, radiometric and photometric detector head assemblies, visible and infrared LED measurement systems, integrating spheres for attenuation and uniform response, detectors with $1cm^2$ active area for convenient flux and spot measurements, low cost detectors with smaller active areas, low profile head assemblies for tight spaces, and special bandpass filters for UV through near infrared measurements.

## 1.4 Calibration

Detector assemblies may be obtained with calibrations stored in a plug-in calibration (PIC) EPROM. Stored information includes data for calibrations with standard filters and accessories for radiometric or photometric measurements, special filters, or specialized detector assemblies for measurements at particular wavelengths such as 632.8nm for HeNe lasers, or continuous calibration data covering a wide spectral range.

If accessories are obtained after initial purchase, either the PIC module can be returned for calibration additions or a new one purchased.

Calibration data includes calibration certification listing model and serial numbers of items calibrated, description of calibration including wavelength, measurement units, special accessories or conditions, and a statement of traceability to NBS. UDT maintains standards and equipment optimized for accurate calibration and recalibration of instruments. The normal period to recalibration is six months. An electrical calibration lab may have the facilities to check the current measurement accuracy of the 370 (see performance verification). In this case only the detector assemblies and PIC modules need be returned for calibration.

UDT keeps calibration data for each instrument on file.

## 2.0 PREPARATION FOR USE

### 2.1 Inspection

Before shipment this instrument was inspected and found to be free of defects. When unpacking, inspect for damage that may have occurred during shipment. If damage is found, file a claim with the carrier and notify the UDT customer service department (see Product Warranty Appendix).

The model 370 shipping container should contain:

1 - Model 370 Optometer
1 - Instruction Manual
1 - Line Cord with IEC Female Connector
1 - Carrying Case
1 - Plug in Calibration Module
A/R - Detector Assemblies Ordered Separately

## 2.2 Instrument Identification

The instrument's model and serial numbers are on a label on the rear panel. The instrument history is maintained in a serial number file at UDT.

## 2.3 Input Power Requirements

The instrument operates on 90-132VAC or 180-264VAC 47-440Hz, 10VA nominal.

Line voltage is selected by a switch on the rear panel power supply circuit board.

The instrument is fused at 1/8 AMP for 115VAC, 1/16 AMP for 230VAC.

Verify proper line voltage and fuse rating prior to operating the instrument.

## 2.4 Packaging for Shipment

The carrying case supplied with the instrument is intended to be used as a shipping, carrying, and storage case. It is recommended that this case be used when returning the instrument for repair and recalibration.

# 3.0 OPERATION

This section describes the switch functions and basic operation of the model 370. Stand alone operation and use of the IEEE-488 interface is described. For an introduction to measurements see the "User's Guide" and "Radiometry and Photometry Once Over Lightly" in the Appendix.

## 3.1 Front Panel Controls

### 3.1.1 Power

Turns on the instrument. The display shows the message "Model S370".

3.1.2 The following touch sensitive switches perform:

Halt Instrument Function
Display Status
Item being Changed is underlined

Autorange/Manual: Changes the range control from auto to manual range or manual range to auto range. When in manual range the gain may be changed by pressing the up/down keys.

Function: Allows selection of measurement type, the first push displays the present function, additional pushes change the function selected to the next one.

Linear: For normal average measurements.

Log: For logarithmic average measurements (dB). For power measurements in watts, a reference unit of mW is used. The display will read X.XX dBmW.

Log Ratio: For logarithmic average ratio measurements of the signal to the previous measurement, which is saved when using this function. To change the reference value, change mode to linear, start measurement, adjust signal and change the mode back to log ratio.

Ratio: Performs linear ratio of the signal to the previous measurement, which is automatically stored when using this function. To change the reference value, change mode to linear, start measurement, adjust signal, and change the mode back to ratio.

Responsivity/User Entered Responsivity:
Displays the set responsivity. Pushing the start/stop key moves cursor from left to right. Pushing up/down key changes values at cursor (sign, value and measurement units). When the last character is set, pushing start/stop key will display measurement units which can then be changed.

Analog/Digital: Changes the digital reading to analog reading or analog reading to digital reading. When in anlalog reading, the scale factor may be changed by pushing the up/down keys. Display returns to the normal scale when start/stop is pushed twice.

Calibration Select: Pushing calibration select displays calibration.

Typical Display: 268R S/N 17790

The message usually contains the detector model number and serial number. Other calibrations are obtained by pressing the up/down key.

Wavelength Select: The calibration status is displayed.

Calibrations at other wavelengths may be obtained by pushing wavelength and then using the up/down keys. The keys will scroll through the available wavelengths with auto repeat if held down.

Zero: Saves previous readings for subtraction from following readings. A cursor will appear on the right side of the display. To implement the zero function, push the zero switch again, a "z" will appear on the right side of the display. The cursor or "z" will not be displayed if the start/stop key is pressed following the zero procedure. To change back to a non-zeroed measurement, press the zero key so that the cursor is obtained on the right side of the display.

If the measurement function is log ratio or ratio, pressing zero in halt mode will display the value of the reference signal.

Start/Stop: Begins or halts the measurement cycle. Pushing start clears the display and begins measurement.

Display Illumination: Turns the display back light on or off.

## 3.2 IEEE-488 Interface

3.2.1 The IEEE interface allows communications between the instrument, a talker/listener, and a controller such as a Hewlett Packard desk top computer equipped with the HPIB interface or any system with an IEEE-488 interface.

As a listener, the instrument terminates communication when ASCII line feed (LF) or end or identify (EOI) is received. Carriage return, commonly sent by HP systems is received and ignored.

Talking is terminated with CRLF, EOI is sent with the last character.

### 3.2.2 Device Address

The device address is factory-set to address code 04. The address code may be changed by resetting dip switch 1 accessed through the rear panel (IEEE address. Then resetting is accomplished by turning the power off and then on again after the display has gone blank. The address is determined by converting the desired address (0 to 31) to a binary number. The value of the least significant bit is 1, the value of the most significant bit is 16. For example, the binary value for the factory-set address of 4 is 00100. Use the tip of a pen or a small tool to set the switches.

### 3.2.3 IEEE Control Codes

The following codes sent via the IEEE bus set the instrument functions. The codes perform the same functions as obtainable from the front panel except that Up/Down key presses are replaced with numbers representing the desired values.

IEEE bus commands "LLO," "GTL," and "SDC" may also be sent to set the instrument in local lockout (front panel controls disabled), go to local (front panel controls enabled), and send device clear. Local lockout is useful to prevent interference with bus operation by accidental contact with the front panel.

### 3.2.4 Typical Bus Operation

The following examples indicate typical operation of the IEEE bus using a HP-85 computer. Characters are interpreted from left to right and are sent as upper case ASCII character strings.

```
OUTPUT 704; "DNK1W200AG"
```

Set for linear measurement, select first calibration from EPROM, wavelength = 200nm, Autorange, and go.

```
OUTPUT 704; "K3W700M7G"
```

Set for third calibration from EPROM at wavelength of 700nm, manual range = 7 and go.

```
OUTPUT 704; "K"
```

Displays the current calibration.

```
OUTPUT 704;"G"
```

Starts measurement cycle.

```
OUTPUT 704;"F"
```

Asks for data. If the instrument is in operation the data will be available at the end of the measurement sequence.

or

```
OUTPUT 704;"HF"
```

Asks for data and halts.

```
ENTER 704; A$
```

Enters data as a string

or

```
ENTER 704; A
```

Enters data as a floating point number.

## TABLE 1

### IEEE CONTROL CODES

| | |
|---|---|
| A | set Autorange |
| B0 | restore screen |
| B1 | blank screen |
| B2 | Turn off backlight |
| B3 | Turn off backlight |
| D | set mode to: DL log, DN linear, DR ratio, DG logratio |
| E0 | digital reading |
| E1 | analog bar reading |
| F | send current reading<br>Data is equal to input current divided by responsivity |
| G | Go |
| H | Halt |
| K | display Caldata |
| Kx | select Caldata x |
| M | set Manual mode, does not change range |
| Mx | set gain to specific exponent 3,4,5,6,7,8,9 |
| R | Send responsivity; R+X.XXXE+XX set responsivity |
| S | send status of current channel to controller<br>Format is MODE_WAVELENGTH_AUTO/MANUAL_GAIN with each datapoint separated by space (ASCII 20h) |
| U | ask for Unit of measure |
| V1 | -set unit to W |
| V2 | -set unit to fc |
| V3 | -set unit to Lux |
| V4 | -set unit to f |
| V5 | -set unit to W/cm2 |
| V6 | -set unit to W/(cm2 * sr) |
| V7 | -set unit to Cd/m2 |
| V8 | -set unit to Lm |
| Wx | set Wavelength 200 to 2000 depending on cal |
| WU | Increments current wavelength by current step |
| WD | Decrements current wavelength by current step |
| X | display status of current channel |
| Zx | set Zero mode, Z to turn off zero mode, Z1 to reset zero mode |
| *MESSAGE* | displays "message" where message is an ASCII String of up to 16 characters |

## 3.3 Data Format

The format of the data string consists of fourteen characters:

±D.DDDDE±DD_S

The first twelve characters are data in floating point notation with six significant digits plus sign, following the E is the exponent which is two significant characters plus sign.

The fourteenth character is a space, separating the status character. These characters are ignored if the data has been entered as a floating point number.

The status character, S indicates

O Overrange - data points have exceeded the full scale range of the A/D converter.

P Previously read - This data has been outputted before.

N Normal - valid new data.

U Undefined - result of indefinable calculation

## 3.4 Typical Operation

Typical operation requires calibration selection and optional selections, manual range control, auto zero, and function.

3.4.1 Select calibration. Measurements may also be calculated externally. Set the instrument for current measurement and calculate the power by dividing the current in amps by the responsivity in amps per unit of measure.

3.4.2 Check that the detector assembly serial number agrees with the serial number of the detector assembly in the calibration status display. Connect the detector to the BNC connector on the rear panel of the instrument.

3.4.3 If the calibration has continuous calibration data, the wavelength of interest should be selected.

3.4.4 Measurements will begin when the start button is pressed. The message "OVERRANGE" will be displayed when the full scale value of the A/D converter is exceeded. The autorange function will normally locate the best measurement range. A message "Undefined" will occur if a divide by zero or log of negative number calculation has been attempted.

3.4.5 Optional Selections

3.4.5.1 Manual/Autorange

Initial selection is for autoranging. A change to manual ranging may be helpful if a time varying signal causes the display to flash, indicating overrange. Push "auto/manual", then the up/down keys to locate the best range, start operation by pressing "start".

3.4.5.2 Zero

Zero stores the present reading for subtraction from the next readings. It is useful when measuring LED or laser power in the presence of ambient light. Turn off, or block the source to be measured while the instrument is operating, then perform the "zero" operation.

## 4.0 THEORY OF OPERATION

4.1 The model 370 contains an analog current to voltage converter, digital interface, processor, IEEE interface, and power supply sections. Normally the instrument is used with photodiodes, which generate photocurrent proportional to the power of incident light. Photodiodes can be silicon, germanium, InGaAs, or other junction or inversion layer types, vacuum or photomultiplier tubes; photoconductive devices may also be used.

### 4.1.1 Preamplifier

Referring to the schematic (Appendix B), the sensor diode is connected to U1, which is an op amp functioning in the transimpedance mode. This stage converts the current from the sensor to signal voltage. The gain of the amplifier (the transimpedance gain) is determined by the resistance in the feedback network. Relays K1 through K3 select gain resistors R1 through R3. Resistor R4 is always in the circuit. Actual gain of the front end, the parallel resistance of R4 and R1 through R3 (if selected) is the gain in volts "out" per amps "in". The second stage, U2 provides voltage gain of 10 to fill in decade gains from $10^3$V/A through $10^9$V/A. Analog output voltages from both channels are available from rear panel BNC connectors.

4.1.2 Digital Electronics

The A/D converter U9 is a 15 bit plus sign integrating converter. The integration period is 100mS which rejects 50 or 60Hz powerline ripple. A 1.235V band gap reference, CR2 provides for ratiometric signal measurement. The precise reference voltage is recorded during test and stored with calibration data.

The microprocessor is a CMOS version of the Z80 operating at a clock frequency of 6MHz. The processor is responsible for system control and data processing.

Digital input and output are handled by U4, a programmable I/O controller. The controller interfaces the processor to the keyboard, display, range select switches, and power supply.

The display is a single line, 16 segment alphanumeric liquid crystal display which uses the ASCII character set in communication with the processor.

The display may be illuminated with the integral electroluminescent panel. A viewing angle adjustment potentiometer is provided on the rear panel to adjust for best contrast. The Texas Instrument TMS9914A IEEE controller, 75160 and 75161 interface buffers provide I/O communications through the IEEE-488 interface.

Switch SW1 at the rear panel determines the IEEE bus address for the instrument. Binary coding is read during power on initialization.

4.1.3 Software

At power on, a start up routine initializes the system and displays the power on message.

The displayed readings are calculated from:

$$\text{Linear} = \frac{\text{A/D data (binary)} \cdot 2 \cdot V_{ref} \cdot \text{Calibration} \cdot \text{A/unit}}{32678 \cdot \text{Gain, V/A}}$$

Logarithmic readings are calculated using $Log_{10}$ software. All data values are calculated using floating point routines.

4.1.4 Power Supply Circuitry

The standard IEC line connector P10, fuse F1 and line voltage selector switch SW2 provide AC voltage to power transformer T1. Isolated low voltage AC from the transformer is rectified, filtered, and regulated to 5VDC by diodes CR5, CR6, Capacitor C7, and U5. U19, a power supply inverter, provides -5V for the analog circuitry.

# APPENDIX A

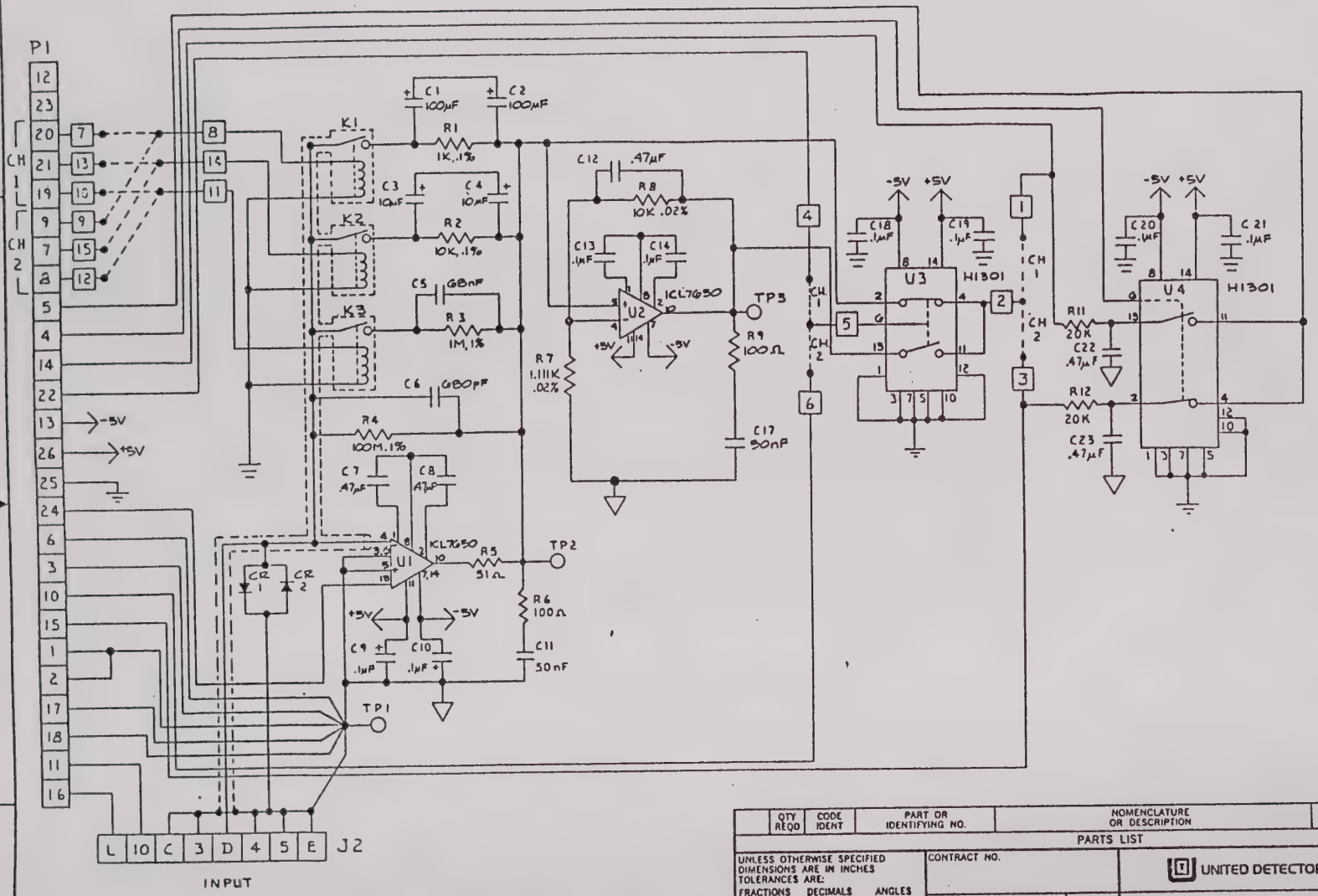
## MODEL 370 DATA SHEET

## APPENDIX B

## SCHEMATIC

THE INFORMATION AND SPECIFICATIONS THAT ARE THE PROPERTY OF UNITED DETECTOR TECHNOLOGY INC. AND SHALL NOT BE REPRODUCED COPIED OR USED IN WHOLE OR IN PART WITH OUT THE WRITTEN CONSENT OF UNITED DETECTOR TECHNOLOGY INC

| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | LTR | DESCRIPTION | DATE | APPR |
| | NC | RELEASE FOR PRODUCTION | 10/29/87 | TD |




| QTY REQD | CODE IDENT | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION |
|---|---|---|---|

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

CONTRACT NO.

UNITED DETECTOR TECHNOLOGY, INC.

| APPROVALS | DATE |
|---|---|
| DRAWN Jeff WIELT | 6/18/87 |
| CHECKED Dave ? | 6/9/87 |

MATERIAL

FINISH

QUALITY:

# SCHEMATIC ANALOG BOARD 380

| SIZE | CODE IDENT NO. | DRAWING NO. |
|---|---|---|
| C | 50486 | 69-01-049 |

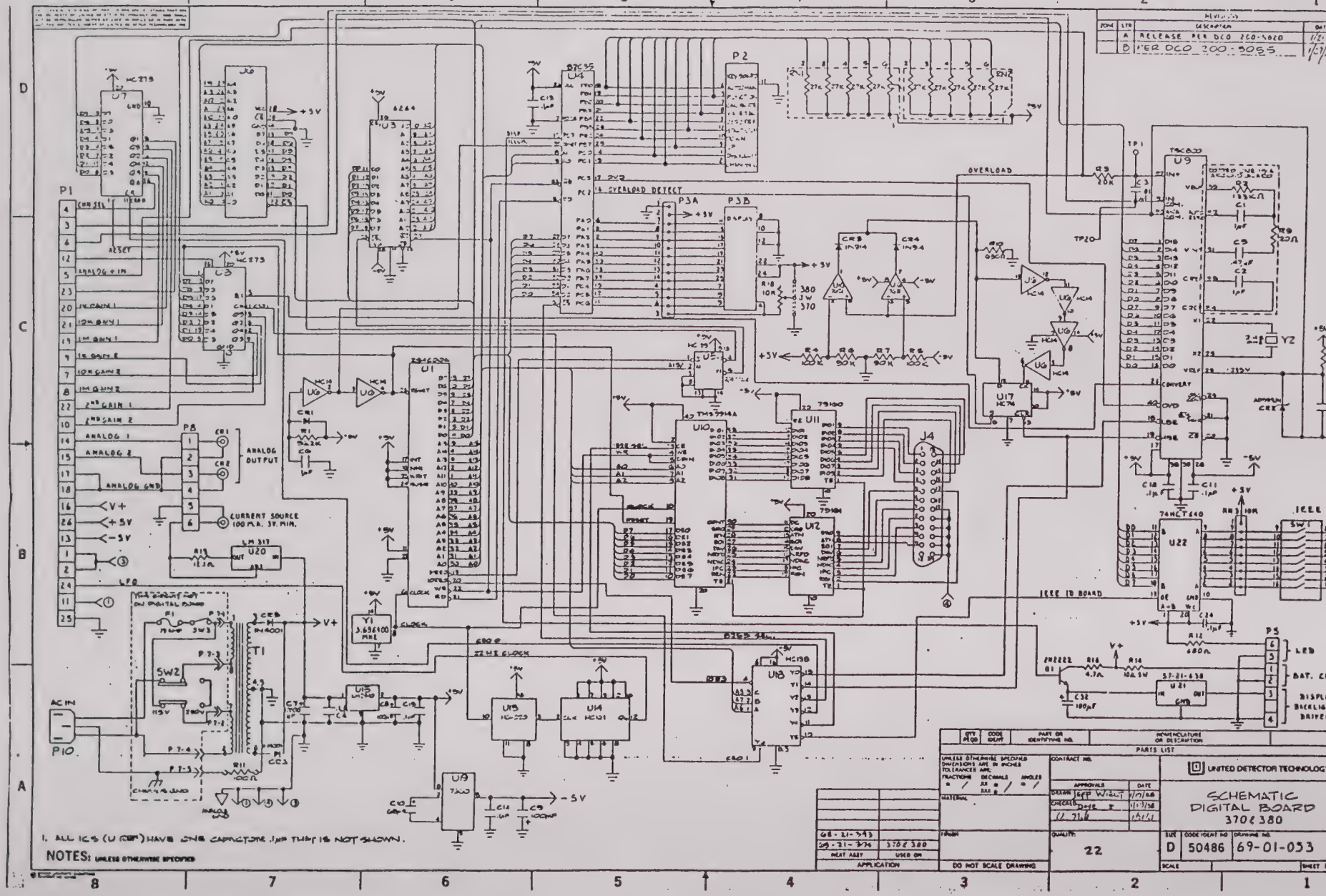
SCALE | SHEET 1 OF

| NEXT ASSY | USED ON |
|---|---|
| 68-21-383 | 380 |

APPLICATION

DO NOT SCALE DRAWING

NOTES: UNLESS OTHERWISE SPECIFIED


P1
P2
P3A
P3B
P8
P10
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
U12
U13
U14
U15
U16
U17
U18
U19
U20
U21
U22
J4
P5
TP1
TP2
SW1
SW2
T1
Y1
Y2
OVERLOAD
OVERLOAD DETECT
ANALOG OUTPUT
CURRENT SOURCE
100 M.A. 3V. MIN.
22 MHz CLOCK
IEEE
IEEE ID BOARD
AC IN
LED
+5V
-5V
+3V
V+
74HCT640
TMS9914A
TMS9914
79190
79T04
LM 317
7660
3.686400 MHz
NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL ICS (U ###) HAVE ONE CAPACITOR .1μF THAT IS NOT SHOWN.
SCHEMATIC
DIGITAL BOARD
370 & 380
UNITED DETECTOR TECHNOLOGY
PARTS LIST
D
50486
69-01-053
22

## APPENDIX C

## PARTS LIST

ASSEMBLY NO..... 21-00-065
ASSY DESCRIPTION. AFG41 MODEL S370 OPTOMETER SYSTEM
REVISION..... A

| PART NUM. | ITM | DESCRIPTION | REF DES | QUANT. | VEND. NM. | AVN DESCRIPTION |
|---|---|---|---|---|---|---|
| 22-00-106 | 1 | TOP ASSEMBLY 370 | | 1 | | |
| 57-91-011 | 4 | 1/8A 250V | F1 | 1 | | |
| 57-91-014 | 5 | FUSE 1/16 AMP 250V | F1 | 1 | | |
| 68-21-388 | 2 | MODULE PLUG IN ASSY | | 1 | | |
| 68-21-389 | 3 | EPROM PCB ASSY | | 1 | | |
| 75-31-005 | 6 | PLUG AND SOCKET LINE CORD | | 1 | | |
| 78-10-026 | 8 | BOX AND INSERT FOAM MODEL 370 | | 1 | | |
| 79-10-032 | 7 | MODEL 370 INSTRUCTION MANUAL | | 1 | | |

ASSEMBLY NO..... 22-00-106
ASSY DESCRIPTION. AAY41 TOP ASSEMBLY 370
REVISION..... B

| PART NUM. | ITM | DESCRIPTION | REF DES | QUANT. | VEND. NM. | AVN DESCRIPTION |
|---|---|---|---|---|---|---|
| 52-01-253 | 19 | JOINT COMPOUND | | 0 | | |
| 57-22-011 | 47 | 5 VOLT REGULATOR | U15 | 1 | | |
| 68-01-306 | 3 | PUSH BUTTON W/BUILT-IN LED 8161J867023 | | 1 | | |
| 68-01-401 | 15 | 115/230 SLIDE (46206LFR) | | 1 | | |
| 68-11-106 | 18 | BNC INSULATED JACK (31-10 AMPHENOL) | | 2 | | |
| 68-11-272 | 46 | CB SHUNT JUMPER CLOSED ENTRY (MSL-260-C) | | 5 | | |
| 68-11-331 | 14 | SP CONNECTOR AC LINE FILTER/CONNECTOR | | 1 | | |
| 68-11-340 | 22 | SP CONNECTOR POWER JACK SWITCHCRAFT 712A | | 1 | | |
| 68-21-383 | 11 | ANALOG PC BOARD A6SY 370/380 | | 1 | | |
| 68-21-393 | 13 | EPROM PCB ASSEMBLY 370/380 | | 1 | | |
| 68-21-394 | 8 | DIGITAL PCB ASSEMBLY 370/380 | | 1 | | |
| 68-21-395 | 7 | LIQUID CRYSTAL DISPLAY 1 LINE 16 CHARACTER | | 1 | | |
| 68-34-396 | 17 | PANEL CLEAR PLASTIC | | 1 | | |
| 68-41-331 | 1 | FRONT PANEL MEMBRANE SWITCH MODEL 370 | | 1 | | |
| 68-41-332 | 2 | BACK PANEL MODEL 370 | | 1 | | |
| 68-61-302 | 16 | HOLDER FUSE 3AG SHOCK PROFF #3AG 345612 | | 1 | | |
| 69-08-063 | 10 | CASE ASSY MODEL 370 BLK | | 1 | | |
| 75-03-200 | 27 | #18 AWG BLACK STRANDED 7/26 TINNED COPPER, P | | 0 | | |
| 75-21-029 | 51 | 3 CONDUCTOR RIBBON ASSEMBLY 4" LONG | | 1 | | |
| 75-41-129 | 26 | BLE 5 PIN FEMALE MOLEX CONNECTOR CABLE | | 1 | | |
| 75-41-130 | 40 | RIBBON SGL ROW/DBL END 2 PIN FEM 3"L | | 1 | | |
| 75-41-131 | 41 | RIBBON SGL ROW/DBL END 14 PIN FEM 3"L | J3A | 1 | | |
| 75-41-132 | 42 | RIBBON DBL ROW/DBL END 26 PIN FEM 4"L | J1 | 1 | | |
| 75-41-133 | 43 | RIBBON SGL ROW/SGL END 4 PIN FEM 9"L | J5 | 1 | | |
| 75-41-134 | 44 | RIBBON SGL ROW/SGL END 6 PIN FEM 9"L | J8 | 1 | | |
| 75-41-135 | 45 | RIBBON 28 COND 7"L SOCKET STRP TO DIP SOCKET | | 1 | | |
| 77-20-332 | 5 | CAGE MODULE MODEL 370 | | 1 | | |
| 77-20-333 | 24 | ANALOG SHIELD COVER MODEL 370 | | 1 | | |
| 77-20-334 | 12 | ANALOG PCB SUPPORT MODEL 370 | | 1 | | |
| 80-15-020 | 39 | 4/40-X-1/2 PHILLIPS PAN HEAD CADIUM PLATED | | 2 | | |
| 80-15-030 | 9 | 4/40 X 1/4 PHILLIPS PAN HEAD, CAD. PLATED | | 21 | | |
| 80-15-034 | 38 | 4/40 X 3/16 PHILLIPS PAN HEAD CAD PLATED | | 4 | | |
| 81-10-023 | 6 | 4/40 LOCK NUT, KEPS | | 14 | | |
| 81-20-033 | 20 | SHOULDER WASHER | | 1 | | |
| 81-20-045 | 33 | 4-40 FLAT NYLON .250 OD X .115 ID .032 THK W | | 3 | | |
| 81-20-056 | 49 | WASHER SS ID 128 | | 1 | | |

| | | | | | |
|---|---|---|---|---|---|
| 81-20-057 | 23 WASHER, SHOULDER .318ID X .5620D | | 1 | | |
| 81-20-058 | 25 WASHER NYLON .315ID X .484OD X .031 THICK | | 1 | | |
| 81-40-029 | 21 INSULATOR THERMA FILM | | 1 | | |
| 81-40-102 | 4 GUIDE, RACK CARD 3.00 LONG | | 2 | | |
| 81-40-125 | 48 HEX 4-40 THREADED X .625 | | 1 | | |
| 81-40-127 | 28 SPACER 3/16 HEX 4-40 X 3/16 M/F | | 4 | | |
| 81-40-128 | 29 SPACER 3/16 HEX 4-40 X 7/16 | | 4 | | |
| 81-40-129 | 30 3/16 HEX 4-40 X 9/16 M/F | | 1 | | |
| 81-40-130 | 31 3/16 HEX 4-40 X 1 1/16 M/F | | 1 | | |
| 81-40-131 | 32 SPACER 3/16 HEX 4-40 X 1 1/8 | | 4 | | |
| 81-40-135 | 34 ROUND CLEARANCE .120 ID X .125 L ALUM | | 4 | | |
| 81-40-136 | 33 3/16 HEX 4-40 3/4L | | 3 | | |

ASSEMBLY NO. ..... 68-21-383
ASSY DESCRIPTION. PCBRD ANALOG PC BOARD ASSY 370/380
REVISION. ..... B

| PART-NUM | ITM-DESCRIPTION | REF-DES | QUANT | VEND. NM. | AVN-DESCRIPTION |
|---|---|---|---|---|---|
| 55-10-110 | 13 MET FLM 100, 1%, 1/8W | R6 | 2 | ITAL ELECTRONIC SALES INC | PN/ RN55D1000F - 1% METAL FILM |
| | | R9 | | HAMILTON/AVNET ELECTRONICS | P/N RN55D1000F - 1% METAL FILM |
| 55-31-810 | 12 MET OX 100M, .1% 25PPM/DEG C | R4 | 1 | VICTOREEN INC. | P/N MOX 400.24 100M 1UV 1/2% |
| | | | | K&M ELECTRONICS, INC | P/N K01268 100M 1UV 1/2% |
| 55-42-051 | 17 CARBON 51, 5%, 1/4W | R5 | 1 | MARSHALL | P/N RCR07G510JS |
| 55-53-210 | 9 MET FLM 1K, .1%, 1/8W | R1 | 1 | HAMILTON/AVNET ELECTRONICS | P/N RN55E1001B |
| 55-53-310 | 15 MET FLM 10K, .1%, 1/8W | R2 | 1 | HAMILTON/AVNET ELECTRONICS | P/N RN55E1002B |
| 55-53-510 | 11 MET FLM 1M, 1%, 1/8W | R3 | 1 | HAMILTON/AVNET ELECTRONICS | P/N RN55E1004B |
| 55-60-006 | 14 RESISTOR 1.111K OHM .02% TOLERANCE | R7 | 1 | HAMILTON/AVNET ELECTRONICS | P/N CMF55-1M-1-T9 P/N PFT56-1111-BC-T10 |
| 55-60-007 | 10 RESISTOR 10K OHM .02% TOLERANCE | R8 | 1 | HAMILTON/AVNET ELECTRONICS | P/N PTF56-10K-BC-J10 |
| 55-99-028 | 16 MET FLM 20K, 1% | R11 | 2 | HAMILTON/AVNET ELECTRONICS | P/N RN55C2002F |
| | | R12 | | | |
| 56-09-042 | 23 CERAMIC, 1UF 50V CERAMIC DIPPED 20% | C10 | 8 | | |
| | | C13 | | | |
| | | C14 | | | |
| | | C18 | | | |
| | | C19 | | | |
| | | C20 | | | |
| | | C21 | | | |
| | | C9 | | | |
| 56-09-168 | 21 CERAMIC 680PF 100VDC 10% | C6 | 1 | | |
| 56-09-356 | 24 CERAMIC .039UF 100VDC 10% RADIAL | C11 | 2 | | |
| | | C17 | | | |
| 56-09-368 | 20 CERAMIC .068UF 50VDC 10% | C5 | 1 | | |
| 56-09-450 | 22 POLYESTER .47UF 63VDC 10% RADIAL | C7 | 2 | | |
| | | C8 | | | |
| 56-12-447 | 25 CERAMIC, 47 UF, 25VDC 5GAT50 XSE500MJKV | C12 | 3 | | |
| | | C22 | | | |
| | | C23 | | | |
| 56-32-610 | 19 TANTALUM 10UF 20VDC DIP | C3 | 2 | | |

| | | | | | |
|---|---|---|---|---|---|
| 56-52-711 | 18 ELECTROLYTIC 100UF 20VDC DIP | C4<br>C1<br>C2 | 2 | | |
| 57-11-006 | 26 14 PIN 641599-3 | MTU2<br>MTU3<br>MTU4 | 3 | | |
| 57-21-298 | 2 CMOS ANALOG SWITCH DUAL SPDT HI3-301-5 | U3<br>U4 | 2 | | |
| 57-21-323 | 4 LOW LEAKAGE FD-300 | CR1<br>CR2 | 2 | | |
| 57-21-504 | 3 PRECISION LOW LEAK RELAY SPST 3501-05-811 | K1<br>K2<br>K3 | 3 | | |
| 57-21-617 | 1 50CPD OPAMP | U1<br>U2 | 2 | | |
| 68-11-230 | 5 CB MALE 13 PIN STRIP DOUBLE ROW .10 CENTER | P1 | 1 | | |
| 68-11-248 | 8 MALE 5 PIN STRIP SINGLE ROW .10 CENTER | P3 | 3 | | |
| 68-11-285 | 7 TEST POINT TERMINAL, BLACK | TP1<br>TP2<br>TP3 | 3 | | |
| 68-11-287 | 6 P.C. EDGE CONNECTOR, 20 PIN RIGHT ANGLE | J2 | 1 | | |
| 68-21-222 | 27 DETAIL ANALOG, S380 | PCBRD | 1 | | |

ASSEMBLY NO..... 68-21-393
ASSY DESCRIPTION. ASZ48 EPROM PCB ASSEMBLY 370/380
REVISION..... A

| PART NUM. | ITM | DESCRIPTION | REF DES | QUANT. | VEND. NM. | AVN DESCRIPTION |
|---|---|---|---|---|---|---|
| 56-09-042 | 3 | CERAMIC .1UF 50V CERAMIC DIPPED 20% | | 1 | | |
| 57-11-011 | 2 | I.C. SOCKET | | 1 | | |
| 68-11-277 | 4 | MALE 15 PIN STRIP DOUBLE ROW .10 CENTER | | 1 | | |
| 68-21-392 | 1 | EPROM PCB DETAIL 370 | | 1 | | |

ASSEMBLY NO..... 68-21-394
ASSY DESCRIPTION. ASZ48 DIGITAL PCB ASSEMBLY 370/380
REVISION..... A

| PART NUM. | ITM | DESCRIPTION | REF DES | QUANT. | VEND. NM. | AVN DESCRIPTION |
|---|---|---|---|---|---|---|
| 52-01-253 | 73 | JOINT COMPOUND | | 0 | | |
| 55-10-009 | 65 | RESISTOR 4.7 OHM 1/8 WATT 1% TOLERANCE | R16 | 1 | ITAL ELECTRONIC SALES INC | 5% CARBON FILM |
| 55-10-110 | 25 | MET FLM 100, 1%, 1/8W | R11 | 1 | ITAL ELECTRONIC SALES INC | PN/ RN55D1000F - 1% METAL FILM |
| | | | | | HAMILTON/AVNET ELECTRONICS | P/N RN55D1000F - 1% METAL FILM |
| 55-10-249 | 23 | MET FLM 4.99K, 1%, 1/8W | R8 | 1 | ITAL ELECTRONIC SALES INC | P/N RN55D4991F - 1% METAL FILM |
| | | | | | HAMILTON/AVNET ELECTRONICS | P/N RN55D4991F -1% METAL FILM |
| 55-10-320 | 29 | MET FLM 20K, 1%, 1/8W | R3 | 1 | ITAL ELECTRONIC SALES INC | P/N RN55D2002F |
| 55-10-356 | 20 | MET FLM 56.2K, 1%, 1/8W | R1 | 1 | HAMILTON/AVNET ELECTRONICS | P/N RN55D5622F |
| 55-10-399 | 22 | MET FLM 90.9K, 1%, 1/8W | R6 | 2 | ITAL ELECTRONIC SALES INC | P/N RN55D9092F |
| | | | R7 | | HAMILTON/AVNET ELECTRONICS | P/N RN55D9092F |
| | | | | | | P/N RN55D9092F |
| 55-10-410 | 21 | MET FLM 100K, 1%, 1/8W | R4 | 2 | ITAL ELECTRONIC SALES INC | P/N RN55D1003F |

| | | | | | |
|---|---|---|---|---|---|
| | | R5 | | | |
| 55-10-413 | 28 MET FLM 133K OHM, 1% 1/8W | R2 | 1 | ITAL ELECTRONIC SALES INC | P/N RN55D1333F |
| 55-100-003 | 27 ARRAY 27K, 6 PIN SIP BUSSED CONFIG. | RN1 | 2 | BELL INDUSTRIES | P/N 4606X101-273 |
| | | RN2 | | | |
| 55-100-004 | 63 ARRAY 10K, 10 PIN SIP BUSSED CONFIG. | RN3 | 1 | BELL INDUSTRIES | P/N 4610X101-103 |
| 55-22-012 | 66 MET FLM 12.1, 1%, 1/4W | R15 | 1 | HAMILTON/AVNET ELECTRONICS | P/N RN60D12R1F |
| 55-42-022 | 24 CARBON 22, 5%, 1/4W | R9 | 1 | ITAL ELECTRONIC SALES INC | |
| 55-42-168 | 26 CARBON 680, 5%, 1/4W | R10 | 2 | MARSHALL | P/N RCR07G681JS |
| | | R12 | | | |
| 55-99-037 | 56 RESISTOR, W.W. 10 OHM, 5 WATT, 5% | R14 | 1 | CYPRESS ELECTRONIC INC | P/N 25J10R |
| 56-04-310 | 58 CERAMIC DISC .01UF 25VDC 20% HY820 SPRAGUE | C3 | 1 | MARSHALL | P/N HY-820 |
| 56-06-611 | 32 POLYPROPYLENE .47UF 160VDC 10% RADIAL | C5 | 1 | | |
| 56-06-612 | 30 POLYSTYRENE 1.0UF 50VDC 10% RADIAL | C1 | 2 | | |
| | | C2 | | | |
| 56-09-042 | 31 CERAMIC, 1UF 50V CERAMIC DIPPED 20% | C11 | 23 | | |
| | | C12 | | | |
| | | C13 | | | |
| | | C14 | | | |
| | | C15 | | | |
| | | C16 | | | |
| | | C18 | | | |
| | | C19 | | | |
| | | C20 | | | |
| | | C21 | | | |
| | | C22 | | | |
| | | C23 | | | |
| | | C24 | | | |
| | | C25 | | | |
| | | C26 | | | |
| | | C27 | | | |
| | | C28 | | | |
| | | C29 | | | |
| | | C30 | | | |
| | | C31 | | | |
| | | C33 | | | |
| | | C34 | | | |
| | | C4 | | | |
| 56-31-510 | 33 TANTALUM 1.0UF 35VDC AXIAL | C6 | 1 | | |
| 56-33-668 | 36 TANTALUM 68 UF 6V 10% | C10 | 1 | | |
| 56-52-710 | 35 ELECTROLYTIC 100UF 16VDC RADIAL | C32 | 3 | | |
| | | C8 | | | |
| | | C9 | | | |
| 56-52-910 | 34 ELECTROLYTIC 10,000UF 16VDC SNAP MOUNT | C7 | 1 | | |
| 57-01-068 | 67 10K OHMS 2W 1 TURN PCB MTG CARBON | R18 | 1 | | |
| 57-11-001 | 48 IC SOCKET, 40 PIN | MTU1 | 4 | | |
| | | MTU10 | | | |
| | | MTU4 | | | |
| | | MTU9 | | | |
| 57-11-002 | 53 IC SOCKET, 8 PIN | MTU16 | 2 | | |
| | | MTU19 | | | |
| 57-11-006 | 52 14 PIN 641599-3 | MTU17 | 2 | | |
| | | MTU6 | | | |
| 57-11-007 | 51 16 PIN 641600-3 | MTU13 | 4 | | |
| | | MTU14 | | | |

| | | | | |
|---|---|---|---|---|
| | | MTU18 | | |
| | | MTU5 | | |
| 57-11-009 | 50 641602-3 AMP 20 PIN | MTU11 | 5 | |
| | | MTU12 | | |
| | | MTU22 | | |
| | | MTU7 | | |
| | | MTU8 | | |
| 57-11-010 | 49 641605-3 AMP 28 PIN | MTJ6 | 2 | |
| | | MTU3 | | |
| 57-21-226 | 60 VOLTAGE REGULATOR LM317T | U20 | 1 | |
| 57-21-262 | 7 TSC800 ADAPTOR CONVERTER W/15 BIT-TSC800 CPL | U9 | 1 | |
| 57-21-263 | 6 74HC273 CMOS OCTAL FLIP-FLOP | U7 | 2 | |
| | | U8 | | |
| 57-21-266 | 3 CMOS INTERFACE ADAPTOR PROGRAMMABLE | U4 | 1 | |
| 57-21-269 | 5 CMOS INVERTER W/HYSTERSIS | U6 | 1 | |
| 57-21-270 | 4 CMOS 2 LINE TO 4 LINE DECODER | U5 | 1 | |
| 57-21-278 | 15 MM74HC74N NATIONAL QUAD. NAND 8 INPUT | U17 | 1 | |
| 57-21-280 | 16 MM74HC138N NATIONAL MULTIPLEXER | U18 | 1 | |
| 57-21-301 | 38 IN 914 | CR1 | 3 | |
| | | CR3 | | |
| | | CR4 | | |
| 57-21-327 | 39 RECITIFIER 1A 100PIV IN4002 | CR5 | 2 | |
| | | CR6 | | |
| 57-21-423 | 62 MPS 2222 | Q1 | 1 | |
| 57-21-609 | 37 TWO TERMINAL IC AD589JH | CR2 | 1 | |
| 57-21-616 | 17 OCPA OPAMP | U19 | 1 | |
| 57-21-638 | 61 ER DRIVER (USE WITH LCD PN 68-21-395) | U21 | 1 | |
| 57-22-001 | 8 IEEE BUS CONTROLLER TI TMS9914ANL | U10 | 1 | |
| 57-22-002 | 9 IEEE BUS BUFFER TI SN75160AN | U11 | 1 | |
| 57-22-003 | 10 IEEE BUS BUFFER TI SN75161AN | U12 | 1 | |
| 57-22-004 | 14 INTERSIL WINDOW COMPARATOR ICL7621BCPA | U16 | 1 | |
| 57-22-005 | 2 8K BYTE X 8 BIT STATIC RAM HM6264LP-15 | U3 | 1 | |
| 57-22-006 | 12 4 BIT BINARY COUNTER TI SN74HC160N | U14 | 1 | |
| 57-22-007 | 11 14 BIT BINARY COUNTER TI SN74HC4020 | U13 | 1 | |
| 57-22-008 | 59 TRI-STATE INVERTING BUFFER MM74HC640N | U22 | 1 | |
| 57-22-009 | 1 IC, CMOS 8-BIT CPU, 6 MHZ TMPZ84C00AP-6 | U1 | 1 | |
| 57-31-001 | 19 2.4576 mHZ CRYSTAL | Y2 | 1 | |
| 57-31-002 | 18 CRYSTAL OSCILLATOR 3.6864 MHZ | Y1 | 1 | |
| 57-61-007 | 40 TRANSFORMER | T1 | 1 | |
| 68-01-601 | 64 DIPSWITCH (76PSB08) | SW1 | 1 | |
| 68-11-230 | 42 CB MALE 13 PIN STRIP DOUBLE ROW .10 CENTER | P1 | 2 | |
| | | P38 | | |
| 68-11-272 | 70 CB SHUNT JUMPER CLOSED ENTRY (MSL-260-G) | | 1 | |
| 68-11-285 | 45 TEST POINT TERMINAL, BLACK | TP1 | 4 | |
| | | TP2 | | |
| | | TP3 | | |
| | | TP4 | | |
| 68-11-288 | 46 CONNECTOR 5 PIN SQUARE WIRE FRICTION LOCK | P7 | 1 | |
| 68-11-352 | 44 SP CONNECTOR IEEE RT ANGLE 24 POS RECEPTACLE | J4 | 1 | |
| 68-11-355 | 72 TERMINAL STRIP 12 PIN .025" SQ | P2 | 2 | |
| | | P5, P8 | | |
| 68-11-356 | 68 TERMINAL STRIP 14 PIN .025" SQ | P3A | 1 | |
| 68-11-357 | 69 TERMINAL STRIP 3 PIN .025" SQ | P9 | 1 | |
| 68-21-391 | 57 DIGITAL PCB DETAIL 370/380 | | 1 | |

# APPENDIX D

## USER ADJUSTMENT, PERFORMANCE VERIFICATION AND CALIBRATION INFORMATION

Sections D.1 and D.2 describe adjustments and measurements to verify the performance of the Model 370. Section D.3 describes the calibration data format in the EPROM.

## D.1 LCD Viewing Angle

The viewing angle of the LCD display may be adjusted by turning the potentiometer on the rear of the instrument. Adjust the potentiometer for best contrast and viewing angle.

## D.2 Performance Verification

The accuracy of the model 370 may be verified using a precision current source such as a Keithley model 220 or equivalent. The model 370 will change range as the signal causes the display to increase beyond 24000 counts. Verify accuracy by comparison of indicated currents to the accuracy table in the specifications section.

## D.3 CALIBRATION DATA FORMAT

Calibration information is stored in the 32K x 8 EPROM starting at hex memory address 6000 in standard Intel hex format. The format of the calibration EPROM is as follows:

| No. | Description | Type | Bytes |
|---|---|---|---|
| 1. | Number of cals | C | 1 |
| 2. | System Voltage Reference | B | 8 |
| 3. | Germanium | C | 1 |
| 4. | Unit | B | 8 |
| 5. | Message 1 | B | 16 |
| 6. | Message 2 | B | 16 |
| 7. | Start of Wavelength | A | 2 |
| 8. | End of Wavelength | A | 2 |
| 9. | Step of Wavelength | A | 2 |
| 10. | Address for Next Cal | C | 2 |
| 11. | Address for Previous Cal | C | 2 |
| 12. | Cal Data floating point, use minus sign for common anode, plus sign for common cathode and conventional current measurement. | B | 10 per calibration |

Note: Repeat numbers 3 to 12 for next cals.
A. For single wavelength:

- wavelength step = 1Ø,
- start wavelength = wavelength For calibration without wavelength information, set start wavelength Th = 0

B. Hex Representation of ASCII Character.
C. Hex Integer

The following is an example calibration.

```
     00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

6000 04 31 2E 32 33 35 30 20 20 00 57 20 20 20 20 20  .1.2350  .W
6010 20 20 30 32 30 30 2D 20 34 30 30 20 6E 6D 20 20    0200- 400 nm
6020 20 20 32 32 32 41 55 56 20 53 2F 4E 20 32 32 30    222AUV S/N 220
6030 20 20 C8 00 90 01 0A 00 0E 61 88 61 2D 2E 30 35    .......a.a-.05
6040 31 32 33 30 30 30 2D 2E 30 37 30 30 32 30 30 30  123000-.07002000
6050 2D 2E 30 39 33 37 30 30 30 30 2D 2E 31 30 35 37  -.09370000-.1057
6060 30 30 30 30 2D 2E 31 31 30 35 30 30 30 30 2D 2E  0000-.11050000-.
6070 31 30 39 39 30 30 30 30 2D 2E 31 30 38 37 30 30  10990000-.108700
6080 30 30 2D 2E 31 30 38 35 30 30 30 30 2D 2E 31 30  00-.10850000-.10
6090 37 38 30 30 30 30 2D 2E 31 31 30 30 30 30 30 30  780000-.11000000
60A0 2D 2E 31 31 35 32 30 30 30 30 2D 2E 31 31 33 37  -.11520000-.1137
60B0 30 30 30 30 2D 2E 31 31 33 30 30 30 30 30 2D 2E  0000-.11300000-.
60C0 31 31 34 38 30 30 30 30 2D 2E 31 32 31 34 30 30  11480000-.121400
60D0 30 30 2D 2E 31 32 35 32 30 30 30 30 2D 2E 31 32  00-.12520000-.12
60E0 31 37 30 30 30 30 2D 2E 31 32 37 33 30 30 30 30  170000-.12730000
60F0 2D 2E 31 34 34 34 30 30 30 30 2D 2E 31 36 37 39  -.14440000-.1679
6100 30 30 30 30 2D 2E 31 37 39 34 30 30 30 30 00 57  0000-.17940000.W
6110 2F 63 6D 32 20 20 20 57 2F 63 6D 32 20 40 33 36  /cm2   W/cm2 @36
6120 35 20 6E 6D 20 20 20 32 34 38 20 53 2F 4E 20 32  5 nm   248 S/N 2
6130 30 34 20 20 20 20 20 00 00 00 00 0A 00 4B 61 09  04      ......Ka.
6140 60 2D 2E 37 39 31 33 45 2D 30 32 00 41 20 20 20  `-.7913E-02.A
6150 20 20 20 20 50 4F 53 49 54 49 56 45 20 43 55 52      POSITIVE CUR
6160 52 45 4E 54 50 4F 53 49 54 49 56 45 20 43 55 52  RENTPOSITIVE CUR
6170 52 45 4E 54 00 00 00 00 0A 00 88 61 0E 61 31 2E  RENT.......a.a1.
6180 30 30 30 30 30 30 30 30 00 41 20 20 20 20 20 20  00000000.A
6190 20 4E 45 47 41 54 49 56 45 20 43 55 52 52 45 4E   NEGATIVE CURREN
61A0 54 4E 45 47 41 54 49 56 45 20 43 55 52 52 45 4E  TNEGATIVE CURREN
61B0 54 00 00 00 00 0A 00 09 60 4B 61 2D 31 2E 30 30  T.......`Ka-1.00
61C0 30 30 30 30 30 00 00 00 00 00 00 FF FF FF FF FF  00000.....
```

# APPENDIX E

## USER'S GUIDE TO THE UDT MODEL 370

## E.1 INTRODUCTION

The purpose of this guide is to describe the most common applications and how typical measurements should be performed with the UDT Radiometers.

The instrument is extremely versatile and has been ergonomically engineered for ease of use. The instrument typically uses a $1cm^2$ silicon planar diffused detector which is extremely rugged and stable. This stability permits calibrations to be held for very long periods for time and permits very low noise, sensitive, linear and accurate measurements to be routinely performed. UDT instrument detectors are sensitive from 350 to 1100 nm (200 nm - 1100 nm for special UV-enhanced detectors with quartz window), can measure power typically from picowatts ($10^{-12}$ watts) to milliwatts ($10^{-3}$ watts) and even to many watts with the appropriate accessories.

For the fundamentals of light measurement the user should consult "Radiometry and Photometry: Once Over Lightly" written by the UDT staff (See Appendix).

### E.1.1. Calibrations

Before using the instrument refer to the detector/instrument calibration sheet. This tells precisely how the particular instrument was calibrated, the units, the channels used, as well as any multiplication factors. This calibration sheet is fundamental to the proper use of the instrument.

In addition to the calibrations listed on the data sheet, almost any meaningful instrument calibration can be performed by the UDT Optical Metrology Department.

### E.1.2 Standard Detector Filters

The radiometric filter supplied with the Model 248 or 262 detector corrects the intrinsic silicon responsivity shown in figure E-1 to a spectrally flat response from 450 nm to 950 nm as shown in figure E-2. This filter, in combination with the UDT instrument detector, permits radiometric (i.e. true thermal power) measurements of either narrow-

band or wideband sources, so long as the entire emitted wavelength is within the flat response range.

The photometric filter supplied with most instruments corrects the silicon curve of figure E-1 to the CIE photometric response of figure E-3. The filter in combination with the UDT instrument detector permits photometric measurements of light (i.e., measurements of the human visual response to light sources).

### E.1.3 Accessories

All general purpose UDT radiometers and photometers use common detectors and accessories. This enables the user to choose from a very wide range of specialized accessories. These include special narrowband filters to isolate parts of the spectrum, color temperature filter sets to measure the blackbody temperature of incandescent sources, red photometric filters to precisely match the red response of the human eye, fiber optic probes, reflex viewing modules to convert the radiometer into a teleradiometer or microradiometer and many other accessories.

In addition special head assemblies are available which allow the user to measure ultraviolet light precisely, as well as heads for measuring Helium-Neon laser compliance and light emitting diode output.

The UDT optional accessories brochure describes the complete range of accessories.

## E.2 ILLUMINANCE MEASUREMENTS

### E.2.1 Purpose

To measure the illuminance of a source such as the illumination level in an office or factory or photographic exposure times.

### E.2.2 Equipment

A - Radiometer/Photometer Indicator Unit
B - detector and cable

C - photometric filter (model 111)
D - diffuser (model 112)

E.2.3 Procedure

1. Connect the instrument to the detector using the cable supplied.

2. Attach the photometric filter onto the detector housing with the filter between the detector and limiting aperture and attach the diffuser onto the filter.

3. Position the head as desired to make the measurement. The conventional measurement of illumination is done with the head positioned at the work plane pointing vertically upward (see figure E-4).

4. Make sure that the measurement is not affected by the shadows from the operator or any other obstacles. The diffuser "sees" objects up to $90^{o}$ away from the aiming direction.

5. Refer to the calibration sheet. This will indicate which channel should be used, what multiplication factors are applicable, and what attachments or other conditions apply. (Normally illuminance measurements are made with a diffuser, however sometimes illuminance measurements are done without the diffuser when high sensitivity is required and when the source is within the detector acceptance angle.

6. Follow the zeroing procedure outlined in the operating section of the manual.

7. Adjust the range switch until a non-full scale reading is obtained. When measuring time varying sources it is advisable to view the analog output (on instruments so equipped) with an oscilloscope to ensure that the front end amplifier does not saturate.

8. See section 7.0 for formulas relating exposure in lux-seconds to film speed.

E.2.4 Typical Measurement Units

-footcandles (lumen/$ft^2$)
-lux (lumen/$m^2$)

## E.3 CW LASER POWER MEASUREMENTS

### E.3.1 Purpose

To determine the total power in a CW laser beam, irradiance from a CW laser, or irradiance from any other
CW light source.

### E.3.2 Equipment

A - Radiometer/Photometer Indicator Unit
B - detector and cable
C - radiometric filter

### E.3.3 Procedure

1. The procedure outlined below and the equipment listed above is specifically applicable to sources with the following characteristics:

   - 450 - 950 nm
   - less than 10 mW total power
   - less than 500 $mW/cm^2$ irradiance

   Special cases falling outside this range are discussed separately.

2. Connect the instrument to the detector using the cable supplied.

3. Attach the radiometric filter onto the detector housing with the filter between the detector and the limiting aperture.

4. Position the head in the laser beam or in the measurement field. (See figure E-5.)

5. Refer to the calibration sheet. This will indicate which channel should be used, what multiplication factors are applicable and what attachments or other conditions apply.

6. Follow the zeroing procedure outlined in the operating manual.

7. Adjust the range switch until a non-full scale reading is obtained.

8. Verify that the radiant flux and irradiance are less than the values stated in step 1.

9. Adjust the detector head in translation and also in tilt while observing the meter, in order to verify that the beam is fully on the detector and no unusual shadowing is taking place.

E.3.4 Typical Measurement Units

- W, mW
- $W/cm^2$, $mW/cm^2$

E.3.5 Procedure For Use With Narrow-band Light Sources Outside the Range 450-950 nm

The set-up described above can be used for sources outside the 450-950 nm range but inside the range 300-1100 nm with the following procedure.

1. Obtain a single point calibration from UDT for use without the radiometric filter at the wavelength of interest.

2. Delete the radiometric filter from the test setup and take the reading as outlined above but using the single point calibration.

E.3.6 Procedure For Use With a Light Source Greater Than 10mW or Greater than 500mW/sq cm Irradiance

By adding one or more of the accessories listed below the measurement range can be extended by the multiplication factor indicated.

| Model # | Description | Multiplier | Comments |
|---|---|---|---|
| 105 | ND 1 filter | 10 | May cause inaccuracies |

| | | | |
|---|---|---|---|
| 105 | ND 2 filter | 100 | because of multiple |
| 107 | ND 3 filter | 1000 | reflections (0.5W max). |
| 2500 | Laser Integrating Sphere | 10,000 | Not spectrally Sphere flat, needs single point calibration (100 W max.). |
| 2525 | LED Integrating Sphere | 1,000 | Not spectrally flat, needs single point calibration (10 W max.). |
| 2550 | Laser Attenuator | 100 | Not spectrally flat, needs single point calibration (0.5W max.). |
| 2575 | Mini Integrating Sphere | 500 | Not spectrally flat, needs single point calibration (10 W max.). |

Refer to the option accessories brochure for the description of the attenuators.

1. Attach the attenuator as shown in figure E-5.

2. Perform the measurement as outlined in section E.3.3.

## E.4 LUMINANCE MEASUREMENTS (ALSO RADIANCE, LUMINOUS AND RADIANT INTENSITY)

### E.4.1 Purpose

To measure the luminance (or radiance) of extended sources such as projection screens, cathode ray tubes, etc. (Also to measure the luminous or radiant intensity of a point source).

### E.4.2 Equipment

A - UDT Indicator Unit
B - detector and cable
C - photometric filter (model 111)
D - $15^{o}$ lumilens (model 1153)

E.4.3 Procedure

1. Connect the instrument to the detector using the cable supplied.

2. Screw the photometric filter onto the detector housing and screw the lumilens onto the filter.

3. Point the head toward the extended source as shown in figure E-6.

4. Make sure that the source is uniform and subtends at least a $15^{o}$ angle at the detector.

5. Refer to the calibration sheet. This will indicate which channel should be used, what multiplication factors and what attachments or other conditions apply.

6. Follow the zeroing procedure outlined in the operating section of the manual.

7. Adjust the range switch until a non-full-scale reading is obtained. When measuring time-varying sources it is advisable to view the analog output (on instruments so equipped) with an oscilloscope to insure that the front end amplifier does not saturate.

8. For luminance measurements or sources smaller than $15^{o}$ use the 1120 reflex viewing module.

E.4.4 Typical Measurement Units

nit (candela/$m^2$) (SI unit)
stilb (candela/$cm^2$)
apostilb (1/ candela/$m^2$)
lambert (1/ candela/$m^2$)
candela/$ft^2$
footlambert (3.426 candela/$m^2$)

E.4.5 Procedure for Radiance

Perform the same procedure as outlined in section E.4.2 but with the radiometric filter in place of the photometric filter. Typical units will be watts/($cm^2$-sr).

E.4.6 Procedure for Luminous or Radiant Intensity

Perform the same procedure as outlined in sections E.4.2 and E.4.3 above using the photometric filter for luminous intensity, the radiometric filter for radiant intensity and substituting a point source which subtends less than a $15^o$ angle at the detector in place of the extended source.

Typical units will be:

- candela (lumen/sr)
- watt/sr

## E.5 MISCELLANEOUS MEASUREMENTS

Utilizing the procedures outlined above, numerous other measurements may be performed. A few representative examples are listed below.

E.5.1 LED Measurements

By using either the UDT Model 129 LED shade or by making a laboratory setup as shown in figure E-7 the luminous or radiant intensity of an LED or lamp may be measured. The procedure is similar to that of section E.3.

E.5.2 Transmission and Absorption Measurements

By interposing a sample between the light source and detector, the transmission or absorption of a sample may be measured.

## E.6 BIBLIOGRAPHY

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London, W.1

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Academic Press,
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New York, NY 10003

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The Chemical Rubber Company
18901 Cranwood Parkway
Cleveland, OH 44128

Color Science, Wyszecki & Stiles,
John Wiley & Sons, Inc., NY

## E.7 FORMULAS

1. Speed of Photographic Materials

E = film exposure for an acceptable print measured in lux-sec)
ASA index = $1/(4E)$
DIN index = $(10 \log E)-5$

2. Illumination of camera image plane

B = brightness of object measured in candelas/sq.ft.
I = illumination on camera image plane in foot candles.
$= B/(4(f\#)^2)$

Illumination at object plane if camera is removed and film placed directly at location of camera image plane

$=$ B(footcandles) = 10.76 B(lux)

## E.8 CONVERSION FACTORS

### LUMINANCE (PHOTOMETRIC BRIGHTNESS) CONVERSION FACTORS

1 NIT = 1 CANDELA/SQUARE METER
1 STIB = 1 CANDELA/SQUARE CENTIMETER
1 APOSTIB (INTERNATIONAL) = 0.1 MILLILAMBERT = 1 BLONDEL
1 APOSTIB (GERMAN HEFNER) = 0.09 MILLILAMBERT
1 LAMBERT = 1000 MILLILAMBERTS

| Multiply Number of To Obtain Number of | By foot-lambert | candella sq.m. | milli-lambert | candela/ sq.in. | candela/ sq.ft. | stilb |
|---|---|---|---|---|---|---|
| footlambert 1 | 0.2919 | 0.929 | 452 | 3.143 | 2,919 | |
| candella/sq.m. | 3.426 | 1 | 3.183 | 1,550 | 10.76 | 10,000 |
| millilambert | 1.076 | 0.3142 | 1 | 487 | 3.382 | 3,142 |
| candela/sq.in. | 0.00221 | 0.000645 | 0.000205 | 1 | 0.00694 | 6.45 |
| candela/sq.ft. | 0.3183 | 0.0929 | 0.2957 | 144 | 1 | 929 |
| stib | 0.00034 | 0.0001 | 0.00032 | 0.155 | 0.00108 | 1 |

### ILLUMINATION CONVERSION FACTORS

683 lumens/watt at 555 nm (max.)

1 watt-second = $10^7$ ergs
1 phot = 1 lumen/sq.cm.

1 footcandle = 1 lumen/sq.ft.

1 lux = 1 lumen/sq.m.
= 1 metercandle

| Multiply Number of To Obtain By Number of | footcandles | lux | phot | milliphot |
|---|---|---|---|---|
| footcandles | 1 | 0.0929 | 929 | 0.929 |
| lux | 10.76 | 1 | 10,000 | 10 |
| phot | 0.00108 | 0.0001 | 1 | 0.0001 |
| milliphot | 1.076 | 0.1 | 1,000 | 1 |

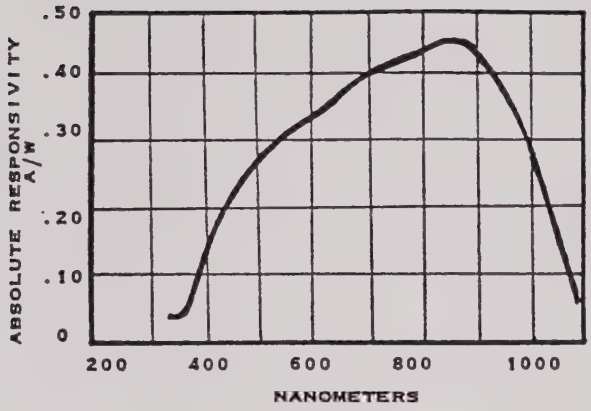



Fig. E-1. Typical Instrument Detector Response

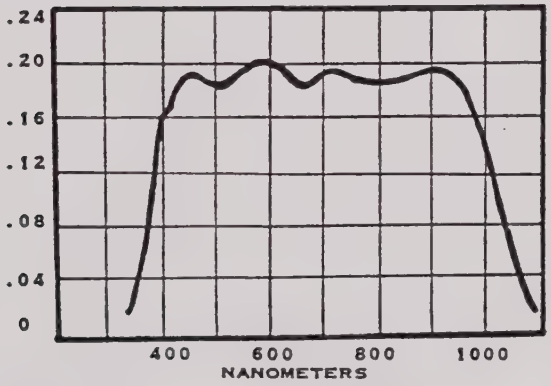



Fig. E-2. Typical Radiometric Filter/Detector Response

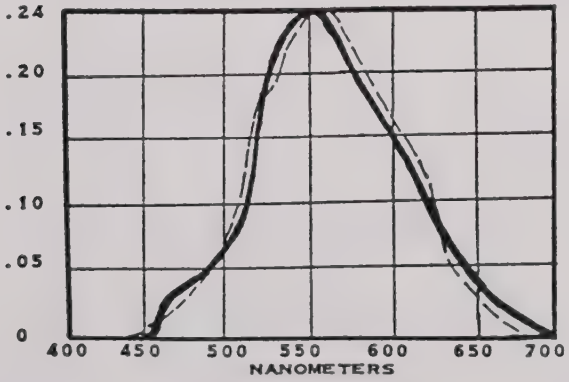



Fig. E-3. Typical Photometric Detector/Filter Response

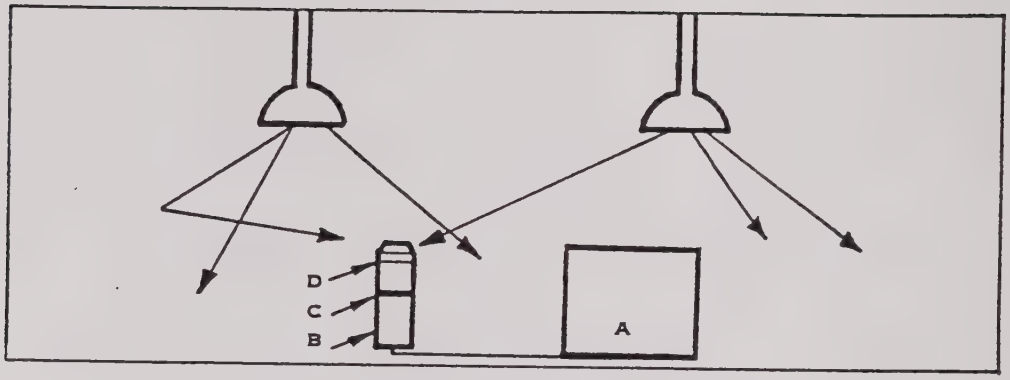



Fig. E-4. Typical Illumination Measurement

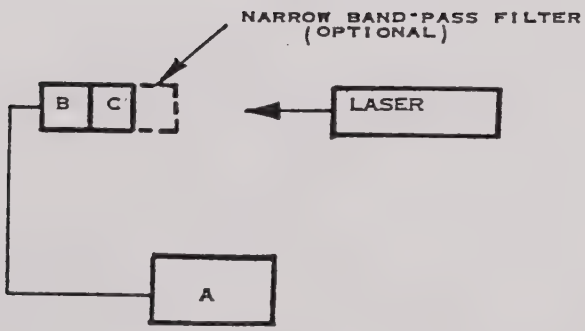



Fig. E-5. Typical Laser Power Measurement

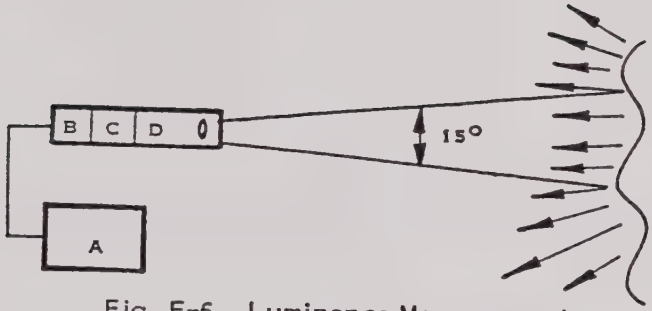



Fig. E-6. Luminance Measurement

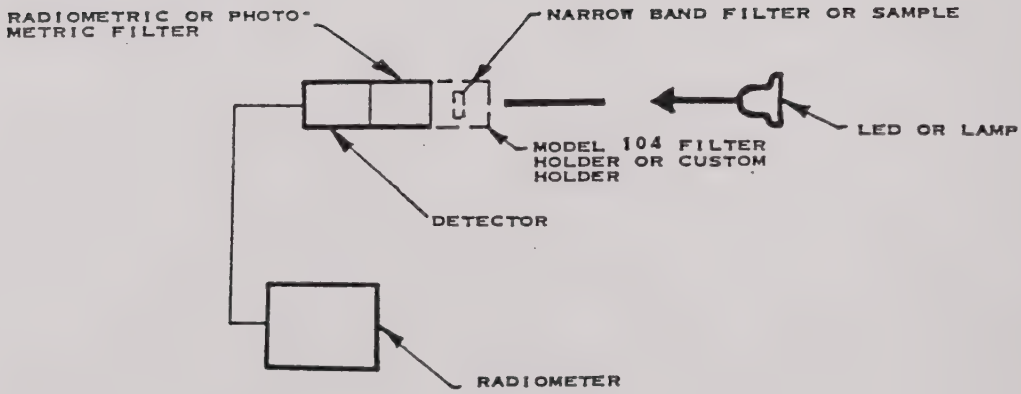



Fig. E-7. LED Measurement

## APPENDIX F

## RADIOMETRY AND PHOTOMETRY ONCE OVER LIGHTLY

by Robert I. Nemhauser, Gil Alexander and Richard Duda

# Radiometry and Photometry: once over lightly

Radiometry and photometry these days are somewhat like enduring businessmen established in industry by necessity and responsibility. Once considered specialized disciplines, they have rapidly adapted to the burgeoning field of electro-optics, which has created new positions for light measurement.

Some of the areas now employing radiometry and photometry include cathode ray tubes; laser scanners for the supermarket point-of-sale systems; liquid crystal displays and light emitting diodes for watches and calculators; holography; lighting regulation (OSHA and suggested Illuminating Engineering Society recommendations); Bureau of Radiological Health regulation — laser and UV damage; photoelectric conveyor controls; horticultural lighting; and construction grading and alignment systems.

And the list of possible applications goes on. It will continue to grow in accordance with our awareness of electro-optical capabilities.

**What is photometry?**

Photometry is the measurement of visible light intensity and energy as it affects the human eye. The visible portion of the frequency spectrum is shown expanded in Figure 1 and covers the band from 400 to 700 nanometers.

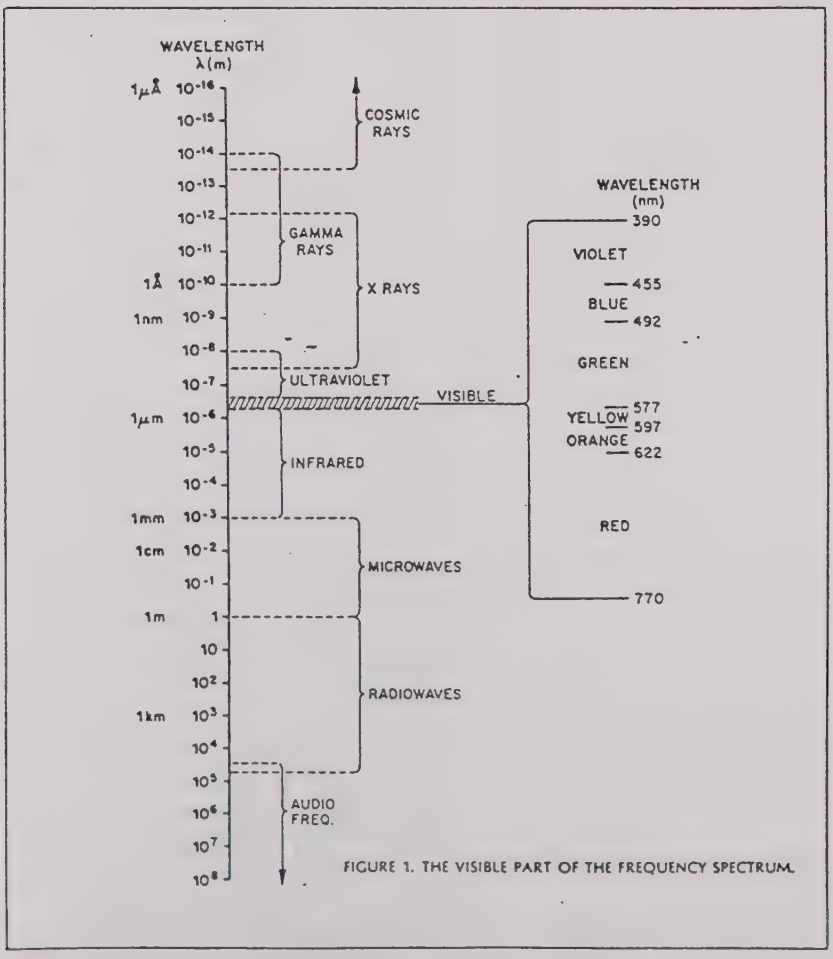



FIGURE 1. THE VISIBLE PART OF THE FREQUENCY SPECTRUM.

To obtain consistent measurement techniques, the response of the average human eye must be defined. This was determined by the Commission Internationale de l'Eclairage (CIE) in 1924 from measurements of the light-adapted eye taken on a sample of the population, and is known as the photopic eye response (Figure 2). The eye has a different response in the dark-adapted state, referred to as scotopic vision, a state in which the eye can no longer determine color. All instruments used for photometry must have sensors with spectral response that match the CIE determined photopic eye response.

Once the average eye is defined, a standard source is required as the basis for a system of units, and the most obvious source, readily available since early times, is the candle. In 1948, the CIE redefined the candle in terms of the light emitted by melting platinum to establish a more consistent basic light standard.

For a basic understanding of photometry, some of the following quantities should be reviewed:

*Luminous flux* — descriptive of radiant power of visible light modified by the eye response. It is the measure of flow of visible light energy past any given point in space, and is defined as the amount of flux generated by a source of one candela into a solid angle of one steradian (Figure 3).

*Power of a source* — the amount of luminous flux emitted from a source into a solid angle. The basic unit of power is the candle, renamed a candela when defined by melting platinum.

*Reprinted from Optical Spectra, April 1976*

In modern industry, radiometry and photometry have shifted to a limitless number of applications to establish their new, broad role.

*Illuminance (or illumination)* — the result of luminous flux striking a surface. In English units, one lumen of flux falling on one square foot of area is defined as an illumination of one footcandle. In metric units, one lumen illuminating one square meter is the definition of one lux. This gives a direct conversion factor 10.76 lux = 1 footcandle (Figure 4).

*Luminance or brightness* — a measure of the flux reflected or emitted from a surface. It has English units of footlamberts and metric units of candelas/square meter. One definition of a footlambert outlines a perfect diffuser uniformly illuminated on one side by one footcandle to have a luminance or brightness of one footlambert on the other side. This perfect diffuser has no transmission loss and diffuses the light with a complete cosine characteristic in all directions. Such a surface is described as Lambertian. While such a diffuser does not exist, its characteristics give rise to a convenient means of relating illumination and luminance (Figure 5).

Photometers with sensors or attachments calibrated in luminance units of footlamberts or candelas/square meter have a fixed field-of-view ranging from ¼° to 15° or larger, and are pointed at the surface to be measured. If the surface has a uniform brightness, the luminance reading is independent of the distance from the surface, providing the entire field-of-view (FOV) is filled. This is illustrated in Figure 6 where a white spot on a dark background is being measured. If the sensor is moved any further from the surface, some of the dark area will be included in the field-of-view; the photometer, which can only measure the average brightness within its field of view, will read low. When making luminance measurements, it is essential to know boundaries of the sensor's field-of-view.

*Luminous energy* — a measure of rate of flow of flux. It has units of lumen-seconds, and might be used to describe such things as the radiant energy that the eye would receive from a photographic flash unit.

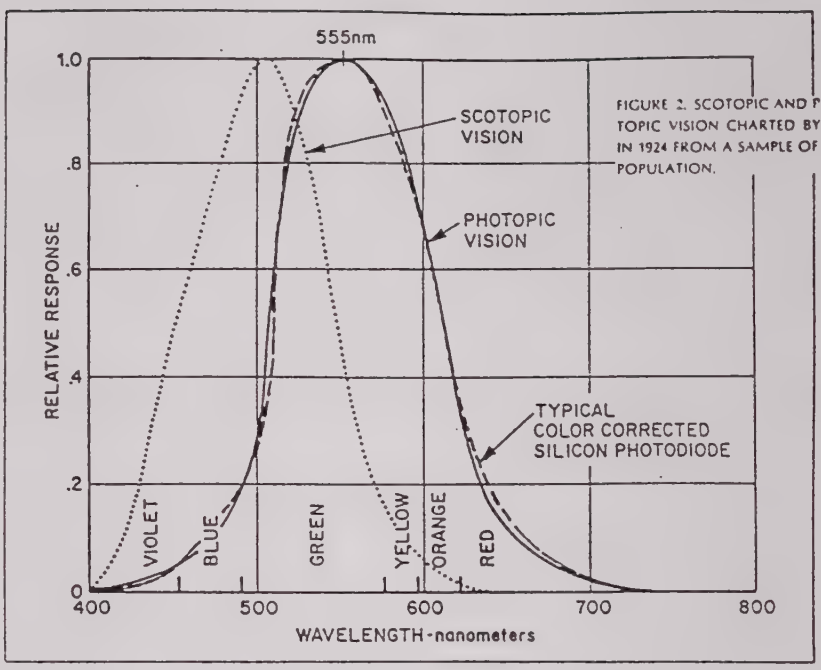
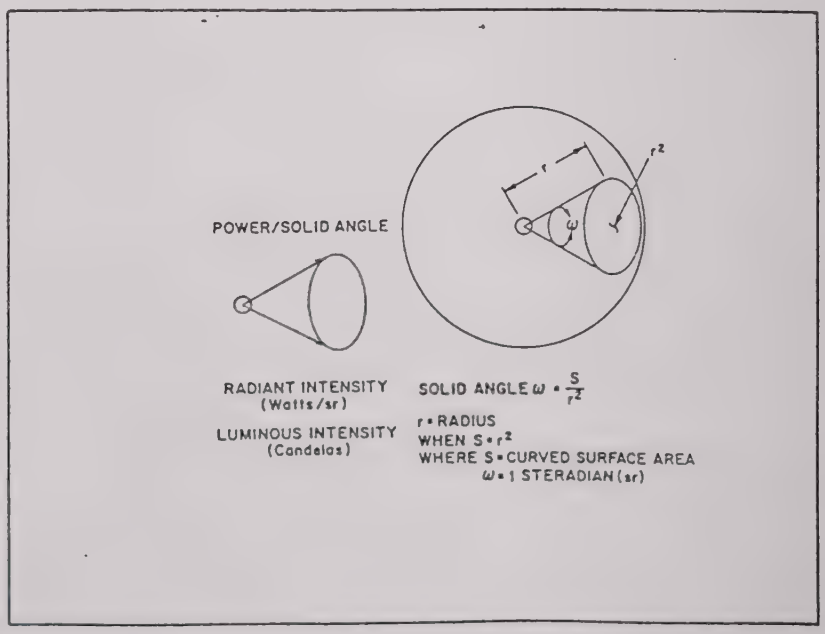


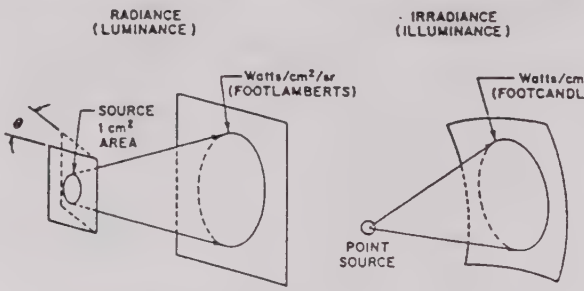

FIGURE 2. SCOTOPIC AND PHOTOPIC VISION CHARTED BY CIE IN 1924 FROM A SAMPLE OF THE POPULATION.

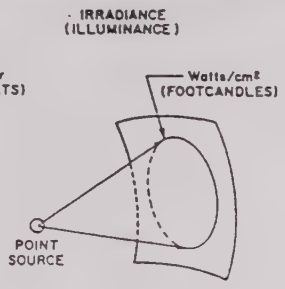
Two laws of illumination can now be introduced: the inverse square law and the cosine law. The first states that illumination of a surface due to a point source is proportional to the intensity of the source and inversely proportional to the square of the distance from the source to the surface (Figure 7). The cosine law indicates that the flux radiated or received in a given direction varies with the projected area of the receiver or emitter in a plane perpendicular to the direction of flux (Figure 8).

In such applications as office lighting, where light sources are not normal to the illumination surface, photometers designed for general use must have a cosine corrected sensor. This correction applies a cosine weighting factor to off-axis light sources. Without the correction, considerable errors will appear if there are bright sources at low incident angles. This often accounts for the difference in readings between two photometers. With careful diffuser

FIGURE 3. LUMINOUS FLUX.






NOTE: 1) THE PROJECTED SOURCE AREA AND THE RECEIVING PLANE MUST BE PARALLEL.

2) THE PROJECTED SOURCE AREA VARIES BY COS θ

FIGURE 4. ILLUMINANCE.

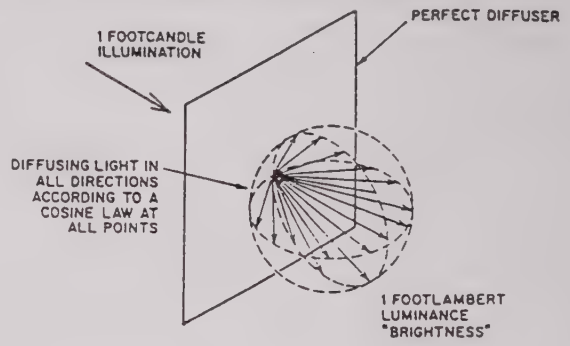



FIGURE 5. LUMINANCE.

design, using either plastic or opal glass, the photometer can be designed with an improved cosine correction at low angles, yielding higher and more correct readings.

But in some laboratory applications, where there is only a single point source of light and the sensor is perpendicular to the luminous flux, a diffuser is not required. In this case, caution should be exercised to ensure that source-to-sensor distance measurements are made to the plane of the sensor, generally a silicon photodiode or photomultiplier tube, and not to the front surface of the glass filter that provides the CIE photopic response. When working at small distances, for example, when measuring Light Emitting Diodes (LEDs), this can be a source of appreciable errors.

### What is radiometry?

Radiometry is the measurement of radiation in the optical spectrum, which includes ultraviolet, visible and infrared light.

Briefly, light consists of a series of colors from the ultraviolet (UV) through the visible and finally to the infrared (IR). And each color of light travels at a given frequency (the number of repetitions per a given period). Light is referred to in units of wavelength which are equivalent to the speed of light divided by the frequency. Assuming a color with the frequency of $10^9$ megahertz, the wavelength can be determined by using equation (1):

$$\lambda = \frac{(3 \times 10^8 \text{ meter/sec})}{(10^9 \text{ Megahertz})} \qquad (1)$$

$$= 3 \times 10^{-7} \text{ m} = 300 \text{ nm (UV light)}$$

The preferred unit in measuring wavelength is nanometers. In all, one nanometer equals ten angstroms, and one-thousand nanometers equals one micrometer (occasionally simplified to micron).

Some basic radiometric terms for review are:

*Radiant flux* — the amount of power incident on a given surface. The unit of power is the watt. For example, a laser has an output in watts. If this laser output underfills a 1 cm²

**Table 1. Photometric/Radiometric Terms**

| QUANTITY | VALUE | UNITS | NAME | ABBREVIATION |
|---|---|---|---|---|
| Energy | | | | |
| Luminous energy | $Q_v$ | Lumen-second | | lm • s |
| Radiant energy | $Q_e$ | Joule | — | J |
| | | Watt-second | — | W • s |
| Flux (power) | | | | |
| Luminous flux | lm | Lumen | Lumen | lm |
| Radiant flux | $Js^{-1}$ | Watt | — | W |
| Power (of source) | | | | |
| Luminous intensity (candlepower) | $lm\ sr^{-1}$ | Lumen/steradian | Candela | cd |
| Radiant intensity | W sr | Watt/steradian | — | — |
| Luminance (photometric brightness) | $lm\ sr^{-1} m^{-2}$ | Candelas/square meter | | nt |
| | | Candelas/square foot | — | — |
| | $\frac{I}{\pi}$ cd $m^{-2}$ | Lumens/steradian/square meter | | asb |
| | $\frac{}{\pi}$ cd $ft^{-2}$ | Lumens/steradian/square foot | Footlambert | fL |
| Radiance | W $sr^{-1}$ $m^{-2}$ | Watts/square meter-steradian | — | — |
| Flux density incident | | | | |
| Irradiance | W $m^{-2}$ | Watts/square meter | — | — |
| Illuminance | lm $m^{-2}$ | Lumens/square meter | Lux | lx |
| (illumination) | | Lumens/square foot | Footcandle | fcd |

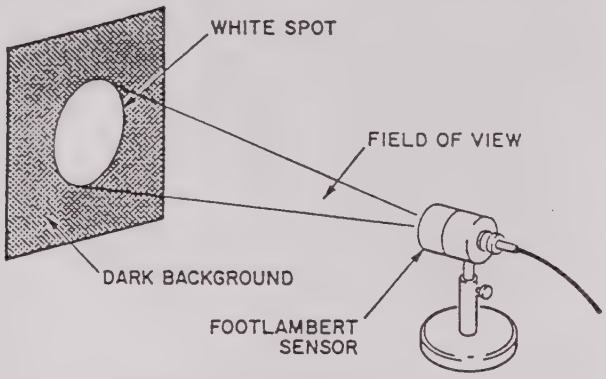



FIGURE 6. THE SENSOR'S FIELD OF VIEW IN MAKING LUMINANCE MEASUREMENTS.

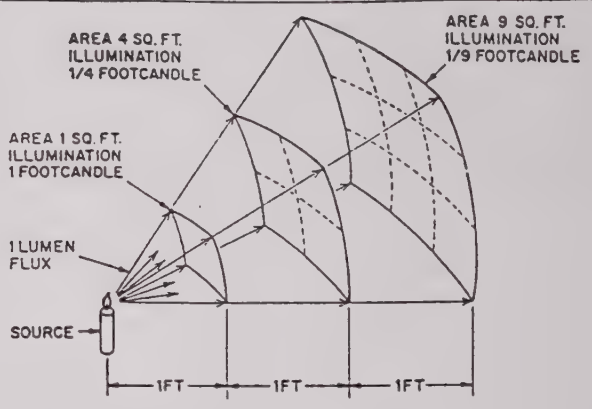



FIGURE 7. THE INVERSE SQUARE LAW.

detector (Figure 9-A), the measurement could be read out on a calibrated radiometer or power meter in watts. If the same laser beam was expanded through a collimator and overfilled a 1 cm² detector (Figure 9-B), the measurement could be read out on the same calibrated radiometer as a power density or watts/cm². By using a 1 cm² detector, the operator has only to ascertain whether he is underfilling or overfilling the sensor. Moreover, a 1 cm² sensor eliminates the need for any calculations of area.

In relating watts to footcandles, the method of conversion requires measurement of spectral energy distribution of a source and its relationship to the energy at each wavelength. An excellent non-technical description is defined in Allen Stimpson's "Photometry and Radiometry for Engineers."

*Radiant intensity (power of source)* — the amount of power from a point source generated in a solid angle (Figure 3). The unit used when making measurements from a point source is the watt/steradian.

*Flux density incident (irradiance)* — the amount of power incident on a surface per unit area. The unit of flux density is the watt/m² (Figure 4).

*Radiance* — the amount of power per unit area per solid area (Figure 4) defined by the unit watt/square meter-steradian. This unit of measurement would be used, for example, when characterizing the output of a point source.

*Radiant energy* — the amount of watts reaching a given point accumulated over a given time interval. This is also referred to as joules (watt-sec) and is illustrated in Figure 10. The radiometric measurements can be related to either a specific wavelength or a band of wavelengths. If a measurement was made of xenon strobe, which is a broadband white light for pulse duration, the energy could be measured in joules. A similar measurement could be performed with a monochromatic (single wavelength) source such as a pulsed ruby laser. In this case, the measurement of the ruby pulse would also be in joules, but would be defined as the flux (power) of that single wavelength over a set duration. A measurement of radiant energy can be made at either a discrete wavelength or an entire spectrum.

## Where is it going?

Recent advances in detector technology are responsible for a merging of the two related but distinctly different disciplines of radiometry and photometry. They share a common portion of the electro-magnetic spectrum (approximately 400 to 700 nanometers) and, as we've already seen, many of the terms have equivalent relationships (Table 1). But applications, measurement techniques and reference standards have shown no evidence of a great deal of interchangability.

In a sense, radiometry is an outgrowth of temperature technology, concerned with thermopiles or other thermal sensors which provide nearly constant response regardless of wavelength. Measurements might range from the total radiation of sunlight to that portion carefully isolated, to a specific narrow wavelength.

Photometry, on the other hand, deals with light as sensed by the eye. Because the eye is not a quantitative device, measurements are necessarily comparative, usually with a lamp as a reference. The case for photoelectric photometry is similar, but absolute values are limited due to problems in long term stability of the sensors.

Recently the National Bureau of Standards developed the concept of an electrically calibrated thermopile. With this device, optical radiation may be directly compared to electrical power, providing high accuracy. In addition, the technology of planar diffused silicon detectors has produced a sensor that combines high sensitivity, linearity of response and long term stability.

As a result, the lumen has been proposed as the new photometric standard to replace the candela. The lumen would be directly and mathematically derived from the radiometric standard, the watt, and would eliminate the need for a physical photometric standard. Then photometry will become a specialized portion of radiometry.

But changes will be both subtle and slow, first affecting only definitions. Although lamp standards will still be necessary, they may be referenced to a group of detectors, rather than a group of similar lamps.

In short, prospects for the future are good. As reference standards and terms are simplified the usage of photometry/radiometry will become as common as the usage of electrical measurements and terms.

## How to use it

Mounting applications for radiometry/photometry present a new problem for the engineer who is inexperienced in making light measurements. He must determine exactly what the measurement requirements are, how the information will be used and what instruments, accessories and

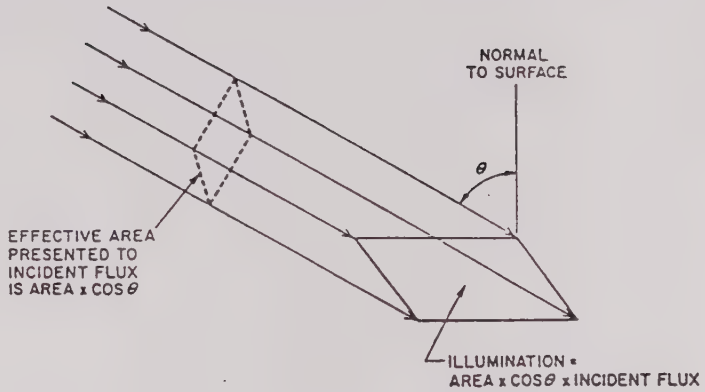



FIGURE 8. THE COSINE LAW.

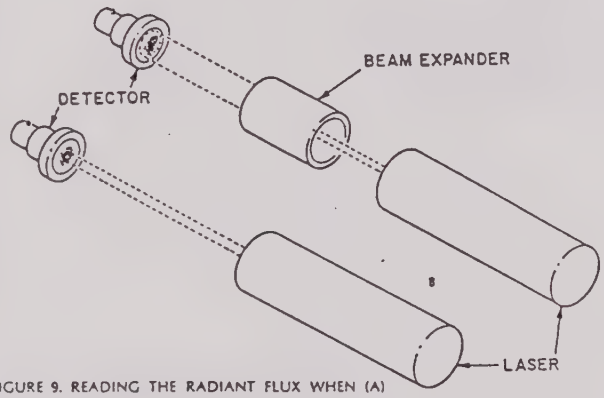
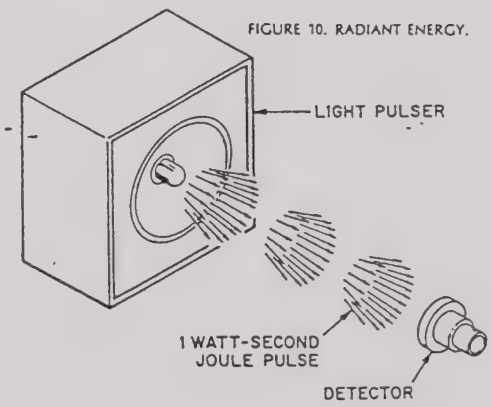



FIGURE 9. READING THE RADIANT FLUX WHEN (A) THE LASER OUTPUT UNDERFILLS THE DETECTOR AND (B) THE LASER OUTPUT OVERFILLS THE DETECTOR.

FIGURE 10. RADIANT ENERGY.




head assemblies are necessary.

Here are examples of areas for consideration in any measurement application:

1. What colors or spectrum are required to be measured? Radiometers that use a silicon photodiode work on the principle shown in Figure 10. The silicon photodiode determines what part of the light spectrum can be measured. If the sensor has a glass window, the radiometer can't measure appreciably below 350nm. If it has a good quality quartz window, it will respond between 200-250nm on the UV side to about 1,150nm on the IR.

2. Does the measurement need to be relative (checking two sources against each other) or absolute (traceable to NBS) and, if so, by what manner?

3. What dynamic range and linearity will be required?

4. What power supply will be needed? DC? AC? Both?

5. Is taut-band meter readout accurately satisfactory or must it be digital?

6. Do you need an analog to drive a scope or recorder?

7. Do you need binary coded decimal (BCD) to drive a printer, or control by an external command, such as a computer?

8. What level of instrument complexity can the operator understand?

9. What is the appropriate head assembly and the correct calibration necessary to measure laser intensity, laser power distribution, xenon strobes output, spectral distribution of lamps, lamp intensity or LEDs?

Last, but most important, consider the source. Never purchase an instrument without fully discussing your requirements with someone qualified to answer questions or anticipate needs. The manufacturer is a logical place to turn. And, no matter how well-suited the instrument is to your specific requirements, direction and assistance with proper operating procedures is vital. □

References

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3. Walsh, John W. T. (1958). Photometry. Dover Publications. New York, N.Y.
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Meet the authors

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## APPENDIX G

## WARRANTY RETURN PROCEDURE
## PRODUCT WARRANTY
## MALFUNCTION REPORT

## Product Warranty and Return Procedure

UDT Instruments warrants the items shipped to be free from defects in material and workmanship, and to conform to current UDTI specifications at the time of sale. Purchaser shall have a period of one year from date of shipment to notify UDTI of a claim under warranty.

UDTI agrees to repair or replace, using new or reconditioned parts, without charge, all items returned within the warranty period, provided that: (1) inspection discloses to the satisfaction of UDTI that the defects are as above specified; and, (2) the material has not been subjected to misuse, improper maintenance, negligence or accident.

The item(s) returned shall only be accepted when accompanied by a written statement describing the nature and suspected cause of the malfunction, please use a copy of the accompanying RETURN REPORT for this purpose.

Returns to UDT Instruments must be shipped prepaid. All shipping and transportation charges shall be the responsibility of the purchaser.

This warranty is in lieu of all other warranties expressed, implied or statutory, and all other obligations or liabilities on the part of UDTI. In no event shall UDTI be liable for claims, demands or damages of any nature, however denominated, except that UDTI's liability shall be to repair in accordance with the terms of this warranty.

If equipment arrives damaged the purchaser should immediately file a claim for damages with the shipping company.

Contact UDT Instruments, Customer Service Department to obtain a Return Authorization Number. Customer Service may also provide more information at this time. The RMA number must appear on the outside of the shipping container for proper receipt.

Repack the instrument securely in the original shipping container or equivalent boxes and packing material. Enclose the RETURN REPORT with the instrument, and ship the instrument to the address shown on the report.

# RETURN REPORT

INCLUDE A COPY OF THIS FORM WHEN RETURNING AN INSTRUMENT FOR SERVICE OR REPAIR.

COMPANY NAME: _____ RMA#: _____
USERS NAME: _____
ADDRESS: _____
CITY: _____

PHONE #: _____ FAX #: _____

INSTRUMENT INFORMATION:
MODEL #: _____ S/N: _____

DETECTOR INFORMATION:
MODEL #: _____ S/N: _____

PROBLEM DESCRIPTION:

DESCRIBE THE PROBLEM, INCLUDE THE INSTRUMENT SETUP:
_____
_____
_____
_____

HOW MANY HOURS DID THE UNIT OPERATE BEFORE THE PROBLEM WAS NOTICED? _____
_____
_____
_____

OTHER COMMENTS: _____
_____
_____
_____

RETURN THE INSTRUMENT TO:

CUSTOMER SERVICE DEPT

UDT INSTRUMENTS
12151 RESEARCH PARKWAY
ORLANDO, FLORIDA 32826

PHONE 407/282-1408
FAX 407/273-9046

www.manualsplus.com
1021411